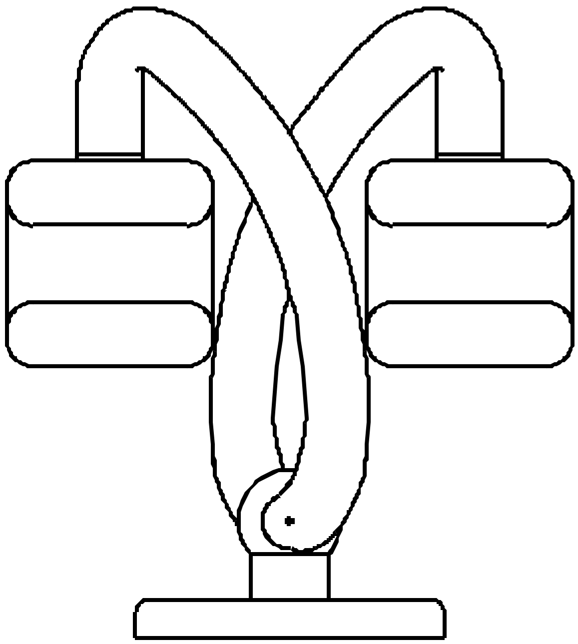
# ATW Production Rates Using Accelerator Mass Spectroscopy



## RIA Applications Workshop 2000

**Richard C. Pardo**
**Physics Division**
**Argonne National Laboratory**
**October 31, 2000**

# Accelerator Mass Spectroscopy

A. Extreme Selectivity in Mass and Element ID.

1. Sensitivity requirements exceed 1 in $10^{12}$
2. Best sensitivity of $8X10^{-16}$ obtained for $^{39}Ar$

B. High Total System Efficiency is Important.

1. Allows preservation of specimen being dated
2. Some applications have very small samples (less than 1000 atoms in case of $^{81}Kr$.)
3. Best efficiency obtained so far is ~2-5%

# Accelerators Used in AMS

A. Tandem Electrostatic Accelerators.

1. Used for: $^{10}Be$, $^{14}C$, $^{26}Al$, $^{36}Cl$, $^{129}I$, $^{236}U$, $^{239,240}Pu$, $^{237}Np$
2. Assets:
    a. Isobar Discrimination in neg. ion formation
    b. Simplicity and Cost
3. Limitations:
    a. negative ion formation limit application
    b. energy may be too low for heaviest radioisotopes

B. Cyclotrons.

1. Used for noble gas AMS – $^{81}Kr$
2. Assets:
    a. High level of $M/\Delta M$ selectivity
    b. Higher energy than electrostatic accelerators
3. Limitations:
    a. No negative ion discrimination possible
    b. Low transmission efficiency
    c. Higher energy brings its own problems

# Accelerators Used in AMS (cont.)

C. ATLAS.

1. Used for development of varied radioisotope detection techniques: $^{39}Ar$, $^{41}Ca$, $^{59}Ni$, $^{60}Fe$, $^{236}U$
2. Combines negative-ion benefits and higher energies for good applications to medium mass range.
3. Assets:
   a. Isobar discrimination in negative ion formation.
   b. Linac adds velocity requirements to $M/\Delta M$ selectivity
   c. Positive-Ion Injector allows development of noble gas AMS.
   d. Higher energy than stand-alone tandem machines
4. Limitations:
   a. More complex than tandem
   b. Energy not as high as cyclotrons
   c. Availability is constrained

# Detection Efficiency

The total detection efficiency determines whether a measurement can be made at the required precision even if the sensitivity is sufficient. Ions can reasonably be expected to be lost at every point along the way.

A. Ion Source:

1. Cesium Negative Ion Source: 0.1% to 5% efficient.
2. ECR Ion Source: 0.1% to 17% ($^{81}Kr^{17+}$).

B. Stripping Efficiency: 20 to 50%. For medium mass ions, at moderate energies 20 - 25% is typical.

C. Bunching Efficiency: 65% (50% if no tandem buncher used)

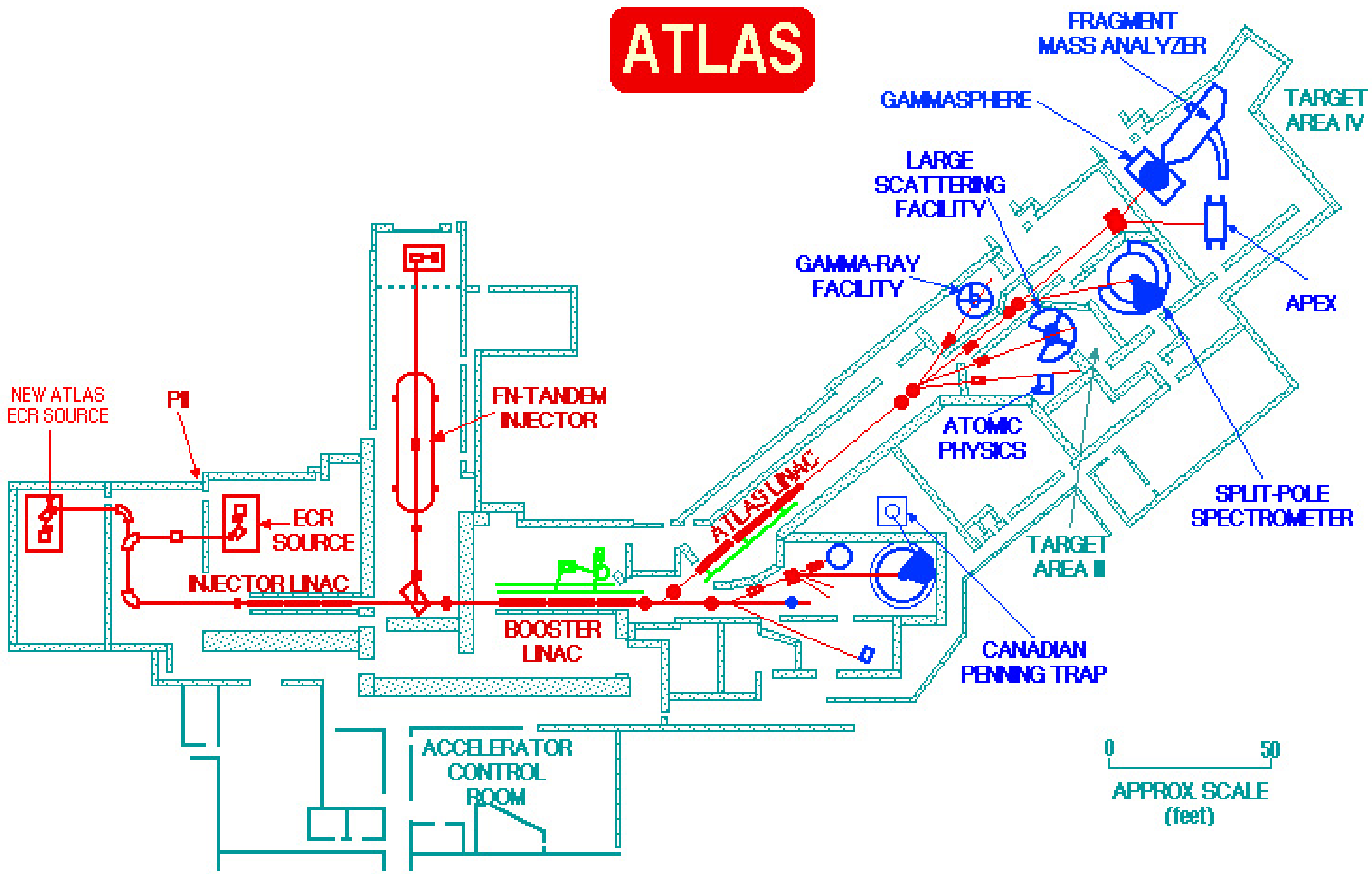
D. Beam Transport Efficiency: 30% typical but can vary considerably.

Typical total efficiency to detector: 0.0065% ($6.5 \times 10^{-5}$)

Summary of Heavy Element AMS Results

| Isotope | $^{236}U$ | $^{236}U$ | $^{239,240}Pu$ | $^{237}Np$ | $^{207}Pb$ |
|---|---|---|---|---|---|
| Laboratory | ATLAS | Racah | ANU | ANU | ATLAS |
| Accelerator | LINAC | Tandem | Tandem | Tandem | LINAC |
| Energy (MeV) | 221 | 85 | 28 | 40 | 192 |
| Mass Selectivity* | $1X10^{-12}$ | $1X10^{-11}$ | _---- | ---- | $1X10^{-14}$ |
| Detection Sensitivity | $10^{7}$ | $10^{8}$ | $10^{7}$ | $10^{7}$ | ------- |

* cannot identify ion "Z" in these measurements.




Floor plan of the ATLAS facility. The ‘new’ ECR source and Injector linac accelerated 236U beam to 276 MeV. The ‘Booster’ linac was used to de-accelerate the beam to 221 MeV, the maximum uranium energy which could be accepted by the the Fragment Mass Analyzer which was used as the detector in this experiment.

# Example Spectra for AMS of $^{236}$U at ATLAS

Title:
e_x23.eps
Creator:
berkova@huphy6 with xmgr
Preview:
This EPS picture was not saved
with a preview included in it.
Comment:
This EPS picture will print to a
PostScript printer, but not to
other types of printers.

Energy versus position of ions arriving at the FMA focal plane detector for a NBS standard 950b. The $^{236}$U/$^{238}$U ratio was approximately $8X10^{-6}$ and required attenuation by a factor of 100 at the ion source.

# Present Limitations of AMS for ATW/SBSS cross sections.

1. Different experiment for each isobar
2. System calibration for efficiency required for each case.
3. AMS precision in this mass range may be only around 10%
4. Sample cross-talk in ion source must be addressed.